ANALYSIS OF HWD DATA FROM CC2 TRAFFIC TESTS AT THE NATIONAL AIRPORT PAVEMENT TEST FACILITY

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ABSTRACT

The National Airport Pavement Test Facility (NAPTF), located at the William J. Hughes Technical Center, was built by the Federal Aviation Administration (FAA) to develop reliable failure criteria for new design procedures for airport pavements, through full-scale testing of the new generation of heavy civil transport aircraft on typical pavement structures. A key element of the NAPTF test program is extensive investigation of material properties, through both destructive tests, and non-destructive testing (NDT) procedures. This paper presents the findings from NDT test conducted during Construction Cycle 2 (CC2) of the NAPTF test program. The focus of CC2 was three rigid pavement test sections constructed on medium-strength subgrade. A 12 inches PCC slab was placed on conventional subbase (MRC), on grade (MRG) and on stabilized subbase (MRS). Each section was 75 feet long by 60 feet wide with 25 feet long by 60 feet wide rigid transitions between them. The slab size was 15 ft. by 15 ft. and the concrete mix included 50% flyash. The FAA's Heavy Weight Deflectometer (HWD), a KUAB Model 240, was used to monitor the pavement deterioration. Readings were taken before the pavement was trafficked and periodically after trafficking started. A total of 15 sets of HWD readings were collected, and were used to track the progress of the pavement deterioration. The level of deflection under a given load provides information about the flexibility of the pavement. Conversely the required load for a unit deflection reflects the local pavement stiffness. This stiffness, called the Impact Stiffness Modulus (ISM), can be used as an indicator of the strength of the pavement. If the ISM, calculated using the maximum basin deflection under the load (D0), is low the pavement can be assumed to be weak. The D7 sensor reading is an indicator of subgrade modulus. An analysis of the D7 sensor data for CC2 shows that the subgrade maintained the designed strength for MRS and MRG test sections. Using the HWD data and the BACKFAA program, the elastic modulus for each layer of the MRS and MRG pavement structures was backcalculated

INTRODUCTION

The National Airport Pavement Test Facility (NAPTF) located at the Federal Aviation Administration (FAA) William J. Hughes Technical Center was built to develop reliable failure criteria for new airport pavement design procedures, through full-scale testing. During the second rigid construction cycle (CC2), which has been described elsewhere [1], non destructive testing (NDT) was used to evaluate the pavement uniformity, the joint efficiency and the deterioration rate of the pavement.

The FAA's Heavy Weight Deflectometer (HWD), a KUAB Model 240, was used to monitor the pavement deterioration rate. Readings were taken before the pavement was trafficked and periodically after trafficking started. A total of 15 sets of HWD readings were collected, and were used to track the progress of the pavement deterioration.

Since the level of deflection under a given load provides an idea about the flexibility of the pavement, the required load for a unit deflection reflects the local pavement stiffness. This paper summarizes the results from the HWD tests performed on the rigid pavements at the NAPTF.

The data have been analyzed to study the structural deterioration using the Impact Stiffness Modulus (ISM) as an indicator of the pavement strength.

CONSTRUCTION CYCLE 2 (CC2)

CC2 consisted primarily of the construction of three rigid pavement test items on medium-strength subgrade. For this purpose, about a 4-ft. depth of medium strength subgrade (CBR between 7 and 8) was rebuilt in a 300 ft. by 60 ft. area. Then 12-inch thick (30.5-cm) PCC slabs were placed on conventional subbase (MRC), on grade (MRG) and on stabilized subbase (MRS) as presented in Table 1. Each test item was 75 ft. (22.9 m) long by 60 ft. (18.3 m) wide with 25 ft. (7.6 m) long by 60 ft. (18.3 m) wide rigid transitions between them (Figure 1). The slab size was 15 ft. (4.6 m) by 15 ft. (4.6 m) and the concrete mix included 50% flyash with a target flexural strength of 700 psi.

Table 1.
CC2 New Rigid Pavement Structure Cross Section.

MRC	MRG	MRS
12-inch P-501	12-inch P-501	12-inch P-501
10-inch P-154	Subgrade CBR 7~8	6-inch P-306
Subgrade CBR 7~8		8.6-inch P-154
		Subgrade CBR 7~8

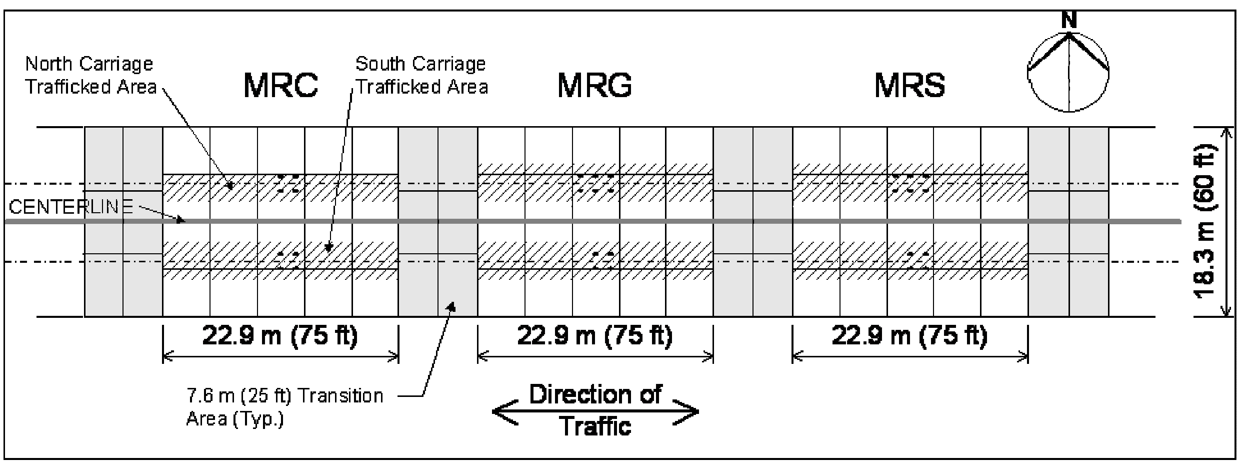

Figure 1. CC2 Rigid Pavement Layout

HEAVY WEIGHT DEFLECTOMETER (HWD)

The FAA's HWD, Kuab Model 240 shown in Figure 2, has been extensively described in [2]. During the CC2 HWD testing, the FAA standard configuration was used: 12-inch (30.5-cm) diameter plate, pulse width of 27-30 msec, and four drop heights: 36-kips (160-kN) seating drop followed by impact loads of 12-kips (53-kN), 24-kips (106-kN), and 36-kips (160 kN).

Figure 2. FAA's KUAB Model 240 HWD Equipment

The deflections were measured at the center of the load plate (D0), at 12-inch (30-cm) offset (D2), 24-inch (60-cm) offset (D3), 36-inch (90-cm) offset (D4), 48-inch (120-cm) offset (D5), 60-inch (150-cm) offset (D6) and 72-inch (180-cm) offset (D7). An additional sensor was placed at 12-in (30-cm) offset (D1) on the front of the loading plate.

PAVEMENT TESTING

The CC2 NDT plan specified the HWD testing locations per test item (MRC, MRG and MRS):

- at the center of each slab, to verify the pavement uniformity, elastic modulus backcalculation for each pavement layer, to track the deterioration of the different support conditions and the deterioration rate of the pavement itself; and

- at the longitudinal and transverse joints of the slabs, to verify the loss of joint load transfer efficiency (LTE).

Originally, CC2 was planned for trafficking using 6-wheel loading (north side) and 4-wheel loading (south side) with 55,000 lbs. (24,950 kg) per wheel at a speed of 2.5 mph (4 km/h) and standard wander pattern of 66 passes per cycle. However, due to the variable flexural strength of the built test items and the short life predicted by FAA design procedures, test item MRC was tested with 4-wheel loading using the standard wander pattern on the south side and an abbreviated wander pattern on the north side. Because of the different loading used in MRC, the HWD data collected from this test item are not comparable to the data collected from MRS and MRG and have not been included in the analysis.

HWD tests were performed every 15 wanders or approximately every 990 passes until 5,000 passes were completed, then every 30 full wanders to 7,000 passes completion, and finally intervals of 60 full wanders for the remainder of the testing. A total of 15 sets of HWD readings were collected, and were used to track the progress of the pavement deterioration. Test items MRS and MRG were trafficked from July 6 until December 10, 2004, when the pavements were declared failed.

Table 2 shows the total number of passes (coverage) applied to final failure on CC2 test items. The pavement deterioration was monitored using periodic distress surveys and HWD. Rolling's structural condition index (SCI) concept [3] was used to declare the pavements failed. A detailed analysis of pavement deterioration in CC2 test items has been discussed by Brill in [4].

Table 2.
Total Number of Passes (Coverage) to Final Failure.

CC2 Test Item	MRG	MRS
South (4-Wheels)	30,996 (6,117)	30,996 (5,784)
North (6-Wheels)	31,020 (6,480)	20,262 (4,855)

Although, the data collected from each of the 15 sets of HWD tests are available, this paper includes the analysis of only 2 sets of HWD data, before the pavement was trafficked and after the traffic was completed.

The level of deflection under a given load provides information about the flexibility of the pavement. Conversely the required load for a unit deflection reflects the local pavement stiffness. This stiffness, called the Impact Stiffness Modulus (ISM), has been used in this paper as an indicator of the strength of the rigid pavement and its rate of deterioration.

STIFFNESS OF RIGID PAVEMENT TEST ITEM MRS

The ISM0, calculated using the maximum basin deflection (D0) under the load, is an indicator of the pavement condition itself.

$$\text{ISM0} = \text{HWD Load}/\text{D0}$$

On the other hand ISM7, calculated using the deflection 72-in from the center load (D7), usually indicates the subgrade condition.

$$\text{ISM7} = \text{HWD Load}/\text{D7}$$

In Figures 3 to 8, to illustrate the pavement behavior, the x-axis has been divided into north and south sides corresponding to 6- and 4-wheel gear load respectively. The station number repeats on both sides of the axis corresponding to the inner/traffic- and outer-lane.

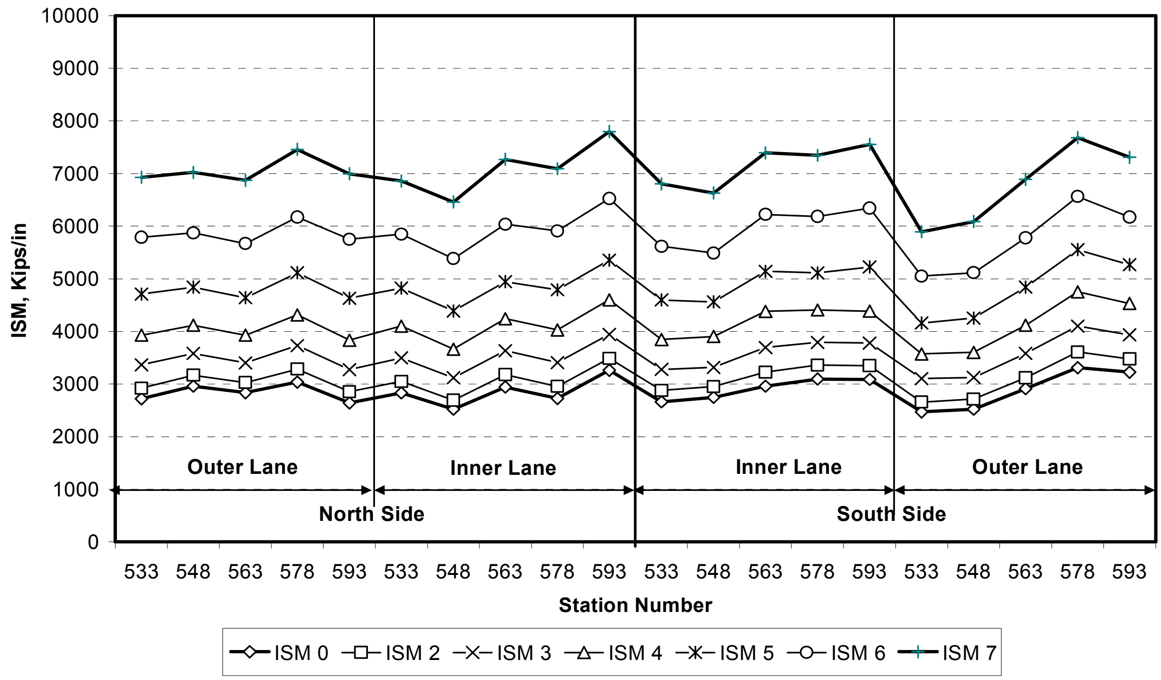

Figure 3. Pavement Stiffness in CC2 MRS Test Item Before Trafficking

To assess the general pavement condition of test item MRS, the ISM corresponding to HWD deflections D0 through D7 is presented in Figure 3 (before traffic) and Figure 4 (pavement declared failed). Figure 3 shows an ISM0 of about 3,000 kips/in for both north and south areas and an average ISM7 of 7,000 kips/in with the exception of the outer lane south side where two stations have values of about 6,000 kips/in.

One of the rules Malvar recommended in [5] states that "*an absolute ISM value below 500 kips/in (87.5kN/mm) should be of concern,*" therefore the MRS test item had a good ISM value before it was trafficked.

Further, Figure 4 shows decay in the ISM0 value which translates into the deterioration of the pavement under traffic. The inner lane of the south area is one of the most affected, where ISM0 drops from approximately 3,000 kips/in to 1000 kips/in. There is also a significant drop in ISM7 value. In Figure 3 the lowest value is 6,000 kips/in and corresponds specifically to the outer lane of the south side where in Figure 4 the value decays below 5,000 kips/in at different locations of the test item including the outer lane of the south side.

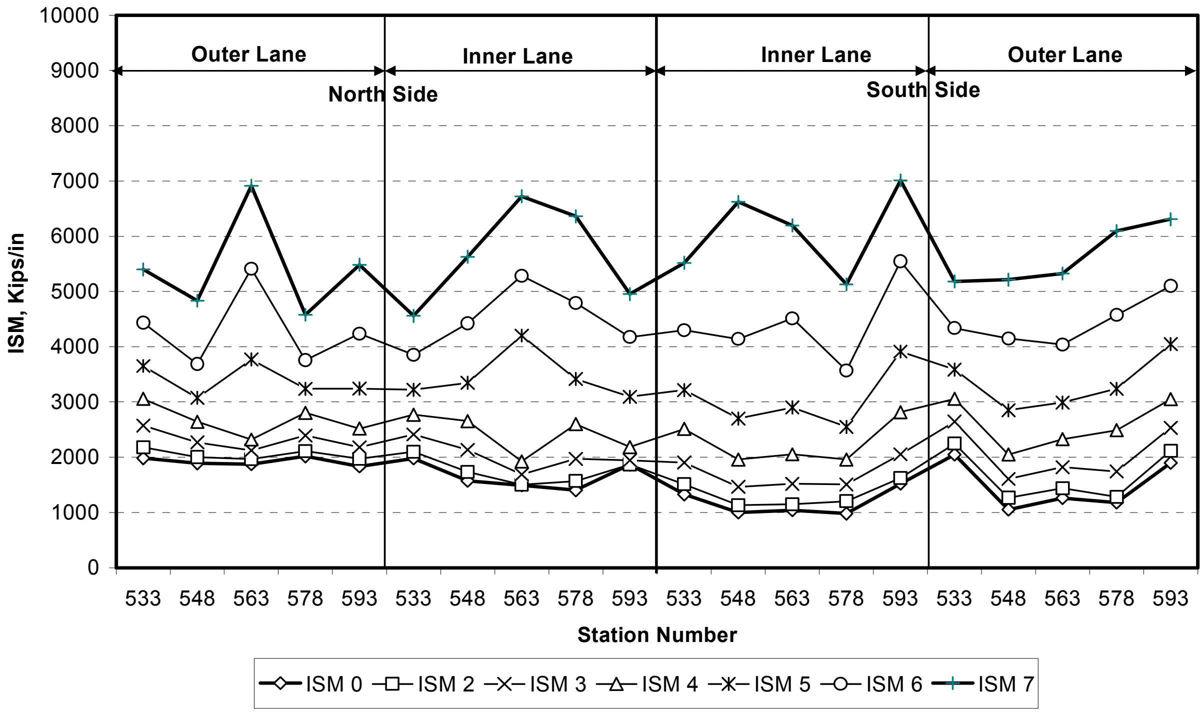

Figure 4. Pavement Stiffness in CC2 MRS Test Item After Trafficking

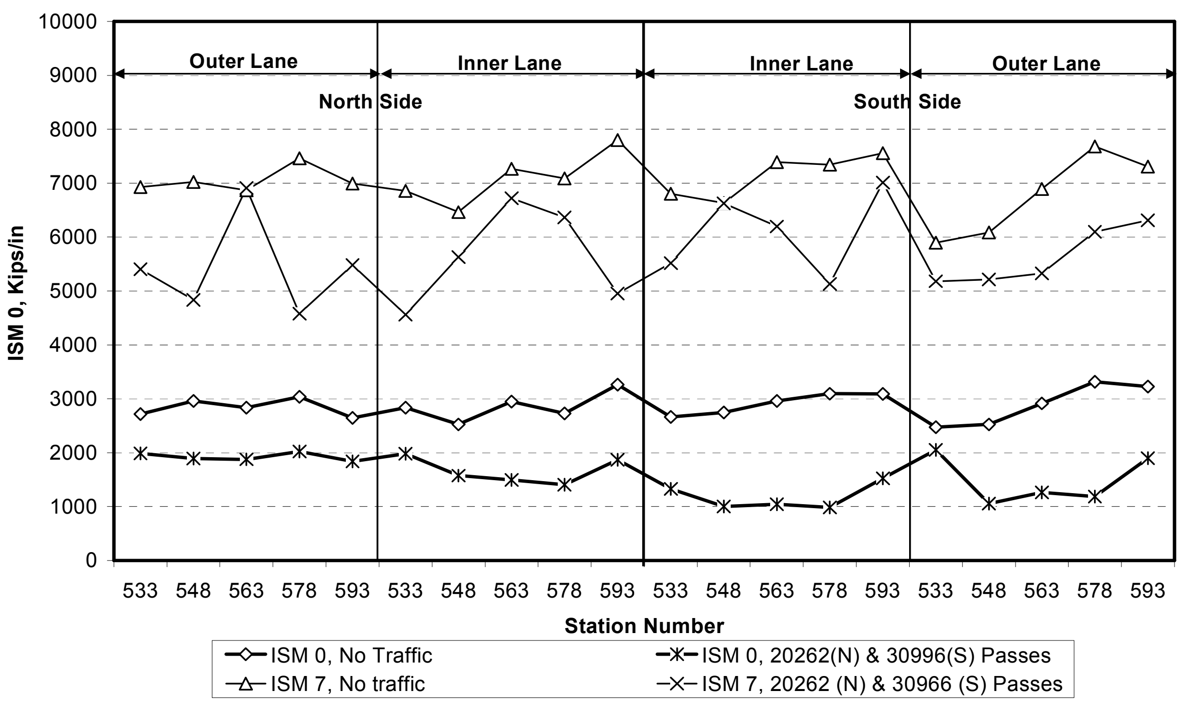

Figure 5. ISM0 and ISM7 Comparison for CC2 MRS Test Item

Table 3.
Average ISM Comparison for CC2 MRS Test Item, kips/inch.

		ISM0		ISM7	
CC2 Test Item	Traffic Lane	No Traffic	After Traffic	No Traffic	After Traffic
	Inner	2,909	1,175	7,146	6,096
South (4-Wheels)	Outer	2,889	1,489	6,773	5,626
	Inner	2,838	1,921	7,055	5,442
North (6-Wheels)	Outer	2,857	1,662	7,096	5,645

The pavement deterioration is more obvious in Figure 5 and Table 3, where only ISM0 and ISM7 values are displayed for MRS before and after traffic was completed. The after traffic plot shows clearly a higher decay on the south side where an additional 10,000 passes were applied compared to the north side.

STIFFNESS OF RIGID PAVEMENT TEST MRG

One of the main differences between test items MRS and MRG is that the MRG structure does not have a subbase layer. Therefore, the pavement behavior and deterioration rate were expected to be different from MRS test item. Loading conditions were identical for both test items, and the north section of MRG was trafficked with 10,000 more passes than MRS.

Figure 6 shows MRG before it was trafficked; the ISM0 average value is lower than for MRS. However, the ISM7 values are consistent with the values from MRS test items. This is an indication of the subgrade homogeneity achieved during the CC2 reconstruction.

The HWD readings in Figure 7 were taken when the pavement was declared failed. It can be observed that an average value for ISM0 of 1,000 kips/in is consistent with the values obtained for MRS, this time for both north and south side which received approximately the same number of passes. However, the values of ISM7 instead of showing reduction in strength of the subgrade, show an increase of about 1000 kips/in.

The plot in Figure 8 and Table 4 allows a better comparison of ISM0 and ISM7. The traffic in MRG originated the failure of the PCC slabs, but the subgrade density apparently increased, translating into higher ISM7 values.

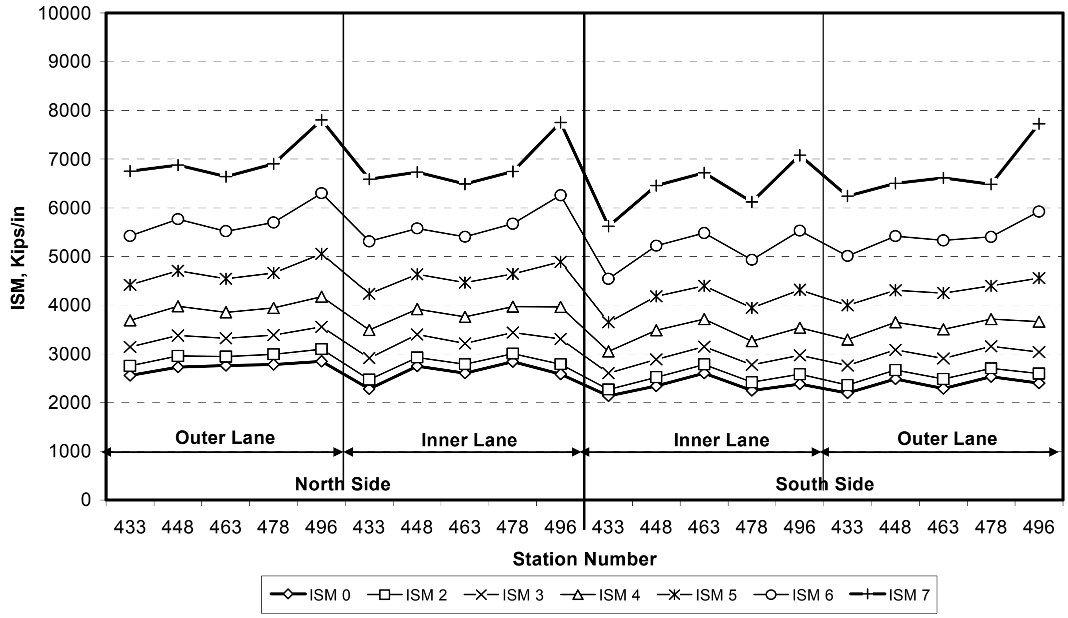

Figure 6. Pavement Stiffness in CC2 MRG Test Item Before Trafficking.

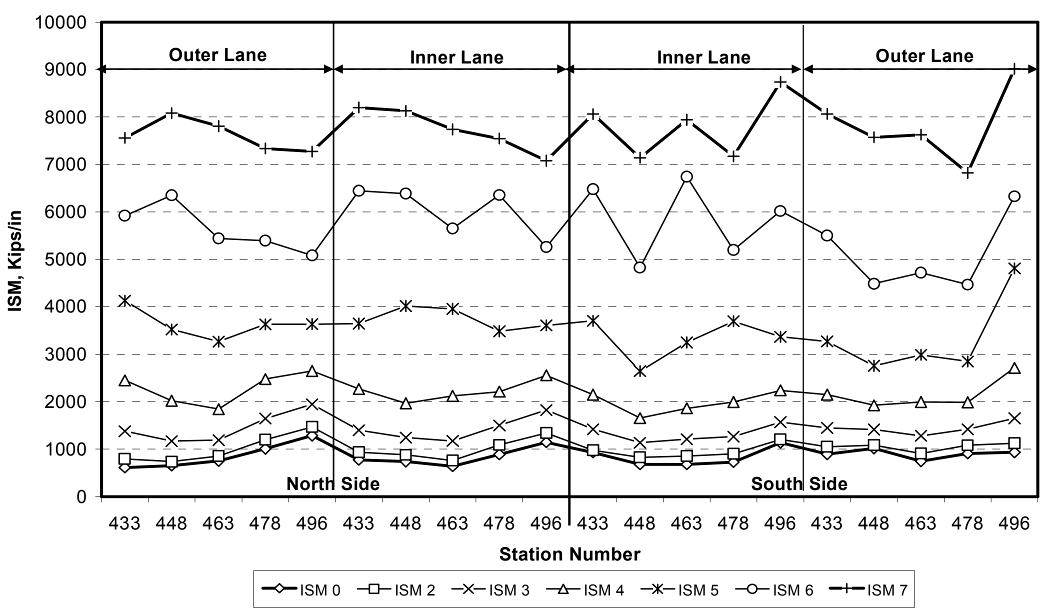

Figure 7. Pavement Stiffness in CC2 MRG Test Item After Trafficking.

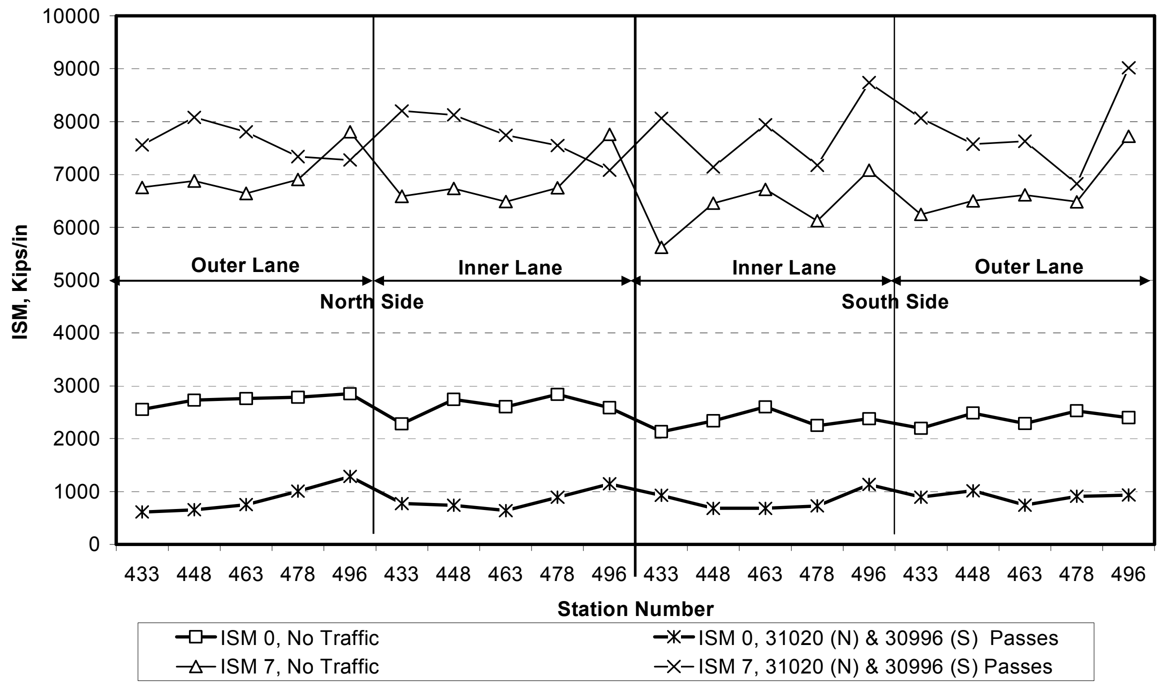

Figure 8. ISM0 and ISM7 Comparison for CC2 MRG Test Item.

Table 4.
Average ISM Comparison for CC2 MRG Test Item, kips/inch.

CC2 Test Item	Traffic Lane	ISM0		ISM7	
		No Traffic	After Traffic	No Traffic	After Traffic
South (4-Wheels)	Inner	2,338	831	6,399	7,811
	Outer	2,379	899	6,712	7,822
North (6-Wheels)	Inner	2,735	861	6,885	7,611
	Outer	2,610	838	6,861	7,738

During CC2 construction, 4-feet of subgrade under MRC and MRG were rebuilt with a target CBR of 8. After trafficking was completed on MRG, the CBR at the surface of the subgrade increased to 11 from the target CBR; but one foot below the surface the CBR dropped to 8.8 inside the traffic path and 8.2 outside. A densification of the subgrade immediately below the PCC slab due to traffic load could explain the CBR values obtained at different depths.

The CC2 MRS subgrade corresponds to the original CC1 built in 1998. The CBR values at the subgrade surface show a reduction from the target CBR to 6.9 inside the traffic path and 6 outside the traffic path. However, one foot below there is an increase in the CBR value to 10.4 and 9.3 respectively. After trafficking was completed in both CC2 and CC2 overlay, several trenches were opened for posttraffic testing. The results of the posttraffic testing can be found in [6].

Table 5 presents the CBR results for MRG and MRS test items from the summary of test results from the trenching study. The results are consistent with the calculated ISM7 values for test items MRG and MRS. An increase in subgrade strength at the surface for MRG and reduction for MRS after trafficking were noted.

Table 5.
CBR Results from Trenching Study [6].

CC2 Test Item	Layer	Inner Lane	Outer Lane
	Subgrade	11	11.2
MRG	1-foot Below Subgrade Surface	8.8	8.2
	Subgrade	6.9	6
MRS	1-foot Below Subgrade Surface	10.4	9.3

SUMMARY

The ISM0 was used to measure the deterioration rate of the PCC slabs during CC2. The subgrade reconstruction homogeneity was verified using the ISM7 values in MRG and MRS test items. Although the PCC slabs decay in MRG and MRS test items had a similar pattern and similar initial ISM0, the final ISM0 for MRG was almost half of the calculated for MRS. This could explain why the subgrade in both cases behaved in opposite ways, decay in MRS and an apparent gain in strength in MRG. This finding is also consistent with the results obtained from the CC2 post traffic testing.

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